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(54) Title: METHOD OF PRODUCING OPEN CELL ALKENYL AROMATIC POLYMER FOAMS (57) Abstract Disclosed is a method of enhancing open cell formation in making extruded alkenyl aromatic polymer foams of about 30 % or more open cell content. Open cell formation is enhanced by incorporating into the foam an ethylene copolymer having a Vicat softening point of about 85 °C or less. The ethylene copolymer is incorporated at from about 0.1 to about 7 percent based upon the weight of the alkenyl aromatic polymer material comprising the foam.		

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METHOD OF PRODUCING OPEN CELL ALKENYL AROMATIC POLYMER FOAMS

The invention relates to a method of enhancing open cell formation in making
5 extruded alkenyl aromatic polymer foams of about 30 percent or more open cell content.

Open cell alkenyl aromatic polymer foams are taught in the art as useful in a variety of end-use applications such as in insulation, roofing recovery, and absorbency. Such foams and applications for them are seen in U.S. Patent Nos. 5,434,195 and 5,557,896 and Canadian Application 2,129,278.

10 A problem in making open cell alkenyl aromatic polymer foams is achieving consistent and elevated levels of open cell content while avoiding high foaming temperatures. High foaming temperatures can cause foam collapse resulting in high foam density and small cross-section.

One means employed in the art to more easily achieve elevated open cell
15 content is to employ loadings (i.e. 3-10 weight percent based upon weight of the alkenyl aromatic polymer) of dissimilar, nonmiscible polymers in the alkenyl aromatic polymer material comprising the foam. The dissimilar, nonmiscible polymers help to open cells by forming domains in the walls of expanding cells. The domains increase the likelihood of pores developing in the walls of cells. In making open cell alkenyl aromatic polymer foams,
20 conventional dissimilar, nonmiscible polymers employed have included polyethylenes such as low density polyethylenes, linear low density polyethylenes, and high density polyethylenes.

There are disadvantages to using the conventional dissimilar, nonmiscible polymers. First, the amounts typically required were relatively high (i.e. 3-10 weight
25 percent). The excessive amounts have resulted in additional expense as well as negatively impacted the physical properties of the end product foam. Second, they have typically exhibited only limited effectiveness in opening cells.

Another means employed in the art to more easily achieve elevated open cell content in extruded alkenyl aromatic polymer foams is to employ elevated foaming
30 temperatures (typically about 135°C or more). However, employing elevated foaming temperatures to produce the desired level of open cell content without foam collapse can be disadvantageous because foaming temperature range may be narrow. If there is foam collapse, foam density may be increased, foam cross-section may be reduced, and skin quality may be negatively impacted.

It would be desirable to have a method for making an open cell alkenyl aromatic polymer foam wherein the desired level of open cell content is more easily and consistently maintained without the need for high loadings of conventional dissimilar polymers. It would also be desirable to have a method for making an open cell alkenyl aromatic polymer foam wherein lower foaming temperatures may be employed.

According to the present invention, there is a method of enhancing open cell formation in making extruded alkenyl aromatic polymer foams of about 30 percent or more open cell content. An alkenyl aromatic polymer material comprising greater than 50 weight percent of alkenyl aromatic monomeric units is heated to form a polymer melt. A nucleating agent may optionally be incorporated into the polymer melt. A blowing agent is incorporated into the polymer melt to form a formable gel. The foamable gel is cooled to a desirable foaming temperature. The formable gel is extruded through a die into a region of reduced pressure to form the foam. A unique aspect of the invention is that an ethylene copolymer having a Vicat softening point of about 85°C or less is incorporated into the polymer melt at from about 0.1 to about 7 percent based upon the weight of the alkenyl aromatic polymer material. The ethylene copolymer significantly enhances open cell formation at relatively low loadings. A preferred ethylene copolymer is ethylene/vinyl acetate.

According to the present invention, there is an extruded, open cell alkenyl aromatic polymer foam. The foam comprises an alkenyl aromatic polymer material comprising greater than 50 percent by weight of alkenyl aromatic monomeric units. The foam has a density of about 16 to about 250 kg/m³, an average cell size of about 1.2 millimeters or less, and an open cell content of about 30 percent or more. The foam has incorporated therein of an ethylene copolymer having a Vicat softening point of about 85°C or less at from about 0.1 to about 7 percent an based upon the weight of the alkenyl aromatic polymer material.

The present invention provides a method for making an open cell alkenyl aromatic polymer foam of about 30 percent or more open cell content by which the desired level open cell content can be more easily and consistently maintained. Further, a foam product of superior quality is produced. Certain ethylene copolymers are incorporated into the foam during its manufacture.

The particular disclosed ethylene copolymers provide distinct advantages over conventional ethylene polymers disclosed in the prior art as useful in increasing open cell content in extruded alkenyl aromatic polymer foams.

One advantage is that the ethylene copolymers may be employed at significantly reduced loadings and still be effective. Reduced loadings afford material cost savings and an end product foams with reduced loadings of incorporated polymer. Reduced loadings may also reduce impact on physical properties of end product foams.

The ethylene copolymers allow foaming temperatures to be reduced and still achieve the desired level of open cell content as opposed to employing elevated foaming temperatures without the ethylene copolymers. Reduction in foaming temperature affords a broader foaming temperature range, lower density, larger cross-section, and better skin quality. Ethylene copolymers have been found to be particularly effective in manufacturing foams of very high open cell content, such as microcellular foams having about 95 percent or more open cell content useful in vacuum panel applications. Ethylene copolymers have enabled such extruded microcellular foams to be produced at conventional processing conditions with low product foam density, large cross-section, and good skin quality.

Useful ethylene copolymers are those with a Vicat softening point of about 85°C or less and preferably about 70°C or less according to ASTM D1525. Preferred ethylene copolymers include those having an ethylene monomeric content of about 50 percent to about 97 percent. The remaining monomeric content may be derived from one or more monomers copolymerizable with ethylene.

Examples of useful ethylene copolymers include ethylene-vinyl acetate copolymer, ethylene-acrylic acid copolymer, ethylene-methacrylic acid copolymer, ethylene-methyl acrylate copolymer, ethylene-ethylacrylate copolymer, ionomers, and ethylene copolymers made with constrained geometry or metallocene catalyst technology.

Useful ionomers include Surlyn® ionomers. Ionomers can be ethylene-methacrylic acid copolymers with zinc, sodium, or lithium cations generated via neutralization. Methacrylic acid content typically is as high as 10 percent.

Ethylene copolymers made with constrained geometry catalyst technology are substantially linear ethylenic polymers having the following physical properties: a melt flow ratio, $I_{10}/I_2 \geq 5.63$; a molecular weight distribution, M_w/M_n , defined by the equation $M_w/M_n < (I_{10}/I_2) - 4.63$; and a critical shear rate at onset of surface melt fracture of at least 50 percent greater than the critical shear rate at the onset of surface melt fracture of a linear olefin

polymer having approximately the same I_2 and M_w/M_n . Excellent teachings directed to such copolymers are seen in U.S. Patent No. 5,340,840, which is incorporated by reference herein. Preferred comonomers include C_{3-10} α -olefins such as 1-propane, isobutylene, 1-butene, 1-hexene, 4-methyl-1-pentene, and 1-octene.

5 A preferred ethylene copolymer is an ethylene/vinyl acetate copolymer. The ethylene vinyl acetate copolymer has from about 5 percent to about 50 percent and preferably about 10 percent to about 40 vinyl acetate monomeric content based upon the total weight of copolymer.

10 The ethylene copolymer is incorporated in the present foam at about 0.1 to about 7 percent, preferably about 0.2 to about 5 percent, and most preferably about 0.3 to about 3 percent based upon the weight of the alkenyl aromatic polymer material.

 The present foam has the density of from about 16 to about 250 kilograms per cubic meter (kg/m^3) and most preferably from about 25 to about 100 kg/m^3 according to ASTM D-1622-88.

15 The present foam has an average cell size of about 1.5 millimeters or less and preferably about 0.001 to about 1.0 millimeters according to ASTM D3576-77.

 The present foam has an open cell content of about 30 percent or more, preferably about 50 percent or more, more preferably about 90 percent or more, and most preferably about 95 percent or more according to ASTM D2856-A.

20 The foam may take any physical configuration known in the art such as sheet or plank. Desirable plank foams include those having a cross-section thickness of about 0.375 inch (0.95 cm) or more.

 Extruded alkenyl aromatic polymer foams are generally prepared by heating a thermoplastic material to form a plasticized or melt polymer material, incorporating therein
25 a blowing agent to form a formable gel, and extruding the gel through a die to form the foam product. Prior to mixing with the blowing agent, the polymer material is heated to a temperature at or above its glass transition temperature or melting point. The blowing agent may be incorporated or mixed into the melt polymer material by any means known in the art such as with an extruder, mixer, blender, or the like. The blowing agent is mixed
30 with the melt polymer material at an elevated pressure sufficient to prevent substantial expansion of the melt polymer material and to generally disperse the blowing agent homogeneously therein. The ethylene copolymer is incorporated by blending and melting in the polymer melt or dry blending with the polymer material prior to plasticizing or melting.

Optionally, a nucleating agent may be incorporated by blending in the polymer melt or dry blending with the polymer material prior to plasticizing or melting. The foamable gel is typically cooled to a lower temperature to optimize or attain desired physical characteristics of the foam. The gel may be cooled in the extruded or other mixing device or in separate coolers. The gel is then extruded or conveyed through a die of desired shape to a zone of reduced or lower pressure to form the foam. The zone of lower pressure is at a pressure lower than that in which the formable gel is maintained prior to extrusion through the die. The lower pressure may be superatmospheric or subatmospheric (vacuum), but is preferably at an atmospheric level. The foaming temperature at the die is maintained at a sufficiently high level to ensure open cell formation.

Suitable alkenyl aromatic polymer materials include alkenyl aromatic homopolymers and copolymers of alkenyl aromatic compounds and copolymerizable ethylenically unsaturated comonomers. The alkenyl aromatic polymer material may further include minor proportions of non-alkenyl aromatic polymers. The alkenyl aromatic polymer material may be comprised solely of one or more alkenyl aromatic homopolymers, one or more alkenyl aromatic copolymers, a blend of one or more of each of alkenyl aromatic homopolymers and copolymers, or blends of any of the foregoing with a non-alkenyl aromatic polymer. Regardless of composition, the alkenyl aromatic polymer material comprises greater than 50 weight percent, preferably about 70 weight percent or more, and preferably greater than 90 weight percent or more alkenyl aromatic monomeric units. Most preferably, the alkenyl aromatic polymer material is comprised entirely of alkenyl aromatic monomeric units.

Suitable alkenyl aromatic polymers include those derived from alkenyl aromatic compounds such as styrene, alpha-methylstyrene, ethylstyrene, vinyl benzene, vinyl toluene, chlorostyrene, and bromostyrene. A preferred alkenyl aromatic polymer is polystyrene. Minor amounts of monoethylenically unsaturated compounds such as C_{2-6} alkyl acids and esters, ionomeric derivatives, and C_{4-6} dienes may be copolymerized with alkenyl aromatic compounds. Examples of copolymerizable compounds include acrylic acid, methacrylic acid, ethacrylic acid, maleic acid, itaconic acid, acrylonitrile, maleic anhydride, methyl acrylate, ethyl acrylate, isobutyl acrylate, n-butyl acrylate, methyl methacrylate, vinyl acetate and butadiene. Preferred foams comprise substantially (i.e., greater than 95 percent by weight) and most preferably entirely of polystyrene.

Blowing agents useful in making the present foam are those known useful in making extruded open cell alkenyl aromatic polymer foams. Useful agents may include

physical and chemical blowing agents. Useful physical blowing agents include inorganic agents and organic blowing agents. Suitable inorganic blowing agents include carbon dioxide, nitrogen, argon, water, air, nitrogen, and helium. Organic blowing agents include aliphatic hydrocarbons having 1-9 carbon atoms, aliphatic alcohols having 1-3 carbon
5 atoms, and fully and partially halogenated aliphatic hydrocarbons having 1-4 carbon atoms. Aliphatic hydrocarbons include methane, ethane, propane, n-butane, isobutane, n-pentane, isopentane, neopentane, and the like. Aliphatic alcohols include methanol, ethanol, n-propanol, and isopropanol. Fully and partially halogenated aliphatic hydrocarbons include fluorocarbons, chlorocarbons, and chlorofluorocarbons. Examples of fluorocarbons include
10 methyl fluoride, perfluoromethane, ethyl fluoride, 1,1-difluoroethane (HFC-152a), 1,1,1-trifluoroethane (HFC-143a), 1,1,1,2-tetrafluoroethane (HFC-134a), 1,1,2,2-tetrafluoromethane (HFC-134), pentafluoroethane, difluoromethane, perfluoroethane, 2,2-difluoropropane, 1,1,1-trifluoropropane, perfluoropropane, dichloropropane, difluoropropane, perfluorobutane, perfluorocyclobutane. Partially
15 halogenated chlorocarbons and chlorofluorocarbons for use in this invention include methyl chloride, methylene chloride, ethyl chloride, 1,1,1-trichloroethane, 1,1-dichloro-1-fluoroethane (HCFC-141b), 1-chloro-1,1-difluoroethane (HCFC-142b), chlorodifluoromethane (HCFC-22), 1,1-dichloro-2,2,2-trifluoroethane (HCFC-123) and 1-chloro-1,2,2,2-tetrafluoroethane (HCFC-124). Fully halogenated chlorofluorocarbons
20 include trichloromonofluoromethane (CFC-11), dichlorodifluoromethane (CFC-12), trichlorotrifluoroethane (CFC-113), 1,1,1-trifluoroethane, pentafluoroethane, dichlorotetrafluoroethane (CFC-114), chloroheptafluoropropane, and dichlorohexafluoropropane. Chemical blowing agents include azodicarbonamide, azadiisobutyronitrile, benzenesulfonhydrazide, 4,4-oxybenzene sulfonyl semicarbazide,
25 p-toluene sulfonyl semi-carbazide, barium azodicarboxylate, N,N'-dimethyl-N,N'-dinitrosoterephthalamide, and trihydrazino triazine.

Teachings to processes for making particular extruded, open cell alkenyl aromatic polymer foams are described below. The ethylene copolymers disclosed herein may be incorporated in those processes to more easily make the open cell foams. The
30 particular open cell foams are disclosed for purposes of description, and are not to be construed as limiting.

Particular useful extruded thermoplastic foams include extruded microcellular alkenyl aromatic polymer foams of high open cell content and processes for making are disclosed in PCT published application WO 96/34038, which is incorporated herein by

reference. The disclosed foams have an average cell size of about 70 micrometers or less and preferably about 5 to about 30 micrometers according to ASTM D3576-77. The disclosed foams have an open cell content of about 70 percent or more and preferably about 95 percent or more according to ASTM D2856-A.

5 In the process disclosed in PCT published application WO 96/34038, useful blowing agents include 1,1-difluoroethane (HFC-152a), 1,1,1-trifluoroethane (HFC-143a), 1,1,1,2-tetrafluoroethane (HFC-134a), chlorodifluoromethane (HCFC-22), carbon dioxide (CO₂), and difluoromethane (HFC-32). Preferred blowing agents are HFC-152a, HFC-134a, and carbon dioxide. The above blowing agents will comprise 50 mole percent or more and
10 preferably 70 percent or more of the total number of moles of blowing agent. The balance may be made up of other blowing agents. The amount of blowing agent employed is from about 0.06 to about 0.17 gram-moles per kilogram of polymer, preferably from about 0.08 to about 0.12 gram-moles per kilogram of polymer, and most preferably from 0.09-0.10 gram-moles per kilogram of polymer. The use of a relatively small amount of blowing agent
15 allows formation of a foam with a high open cell content. Preferred foaming temperatures are disclosed as varying from about 118°C to about 160°C. Most preferred foaming temperatures are disclosed as varying from about 125°C to about 135°C. In the present invention, it was found that useful foaming temperatures could be reduced to as low as about 113°C. Useful nucleating agents additives include inorganic substances such as
20 calcium carbonate, talc, clay, titanium oxide, silica, barium sulfate, calcium stearate, styrene/maleic anhydride copolymer, diatomaceous earth, mixtures of citric acid and sodium bicarbonate, and the like. The amount of nucleating agent employed may range from about 0.01 to about 5 parts by weight per hundred parts by weight of a polymer resin. The preferred range is from 0.1 to about 3 parts by weight.

25 Another useful extruded alkenyl aromatic foam of larger average cell size and processes for making are seen in WO 96/00258, which is incorporated herein by reference. Open-cell content is about 30 percent or more according to ASTM D2856-87. The disclosed foams have a density of about 1.5 pcf to about 6.0 pcf (about 24 kg/m³ to about 96 kg/m³) and preferably a density of about 1.8 pcf to about 3.5 pcf (about 32 kg/m³ to
30 about 48 kg/m³) according to ASTM D-1622-88. The disclosed foam has an average cell size of from about 0.08 millimeters (mm) to about 1.2 mm and preferably from about 0.10 mm to about 0.9 mm according to ASTM D3576-77.

In the process for making the foam in WO 96/00258, the foaming temperature, which is relatively higher than that for making closed-cell foams (less than 10

percent open-cell according to ASTM D2856-87), is disclosed as varying from about 118°C to about 145°C. Foaming temperature will vary according to nucleating agent composition and concentration, blowing agent composition and concentration, polymer material characteristics, and extrusion die design. The foaming temperature for the open-cell foam is disclosed as varying from about 3°C to about 15°C and preferably about 10°C to about 15°C higher than the highest foaming temperature for a corresponding closed-cell foam (less than 10 percent open-cell according to ASTM D2856-87) of substantially equivalent density and cell size made with a substantially equivalent composition (including polymer material, nucleating agent, additives, and blowing agent) in a substantially equivalent process. A preferred foaming temperature is disclosed as being about 33°C or more higher than the glass transition temperature (according to ASTM D-3418) of the alkenyl aromatic polymer material. A most preferred foaming temperature is disclosed as varying from about 135°C to about 140°C. In the present invention, it was found that useful foaming temperatures could be reduced to as low as about 113°C. The amount of blowing agent incorporated into the polymer melt material to make a foam-forming gel is from about 0.2 to about 5.0 gram-moles per kilogram of polymer, preferably from about 0.5 to about 3.0 gram-moles per kilogram of polymer, and most preferably from about 0.7 to 2.0 gram-moles per kilogram of polymer. A nucleating agent such as those described above may be employed.

Various additives may be incorporated in the present foam such as inorganic fillers, pigments, antioxidants, acid scavengers, processing acids, extrusion acids, flame retardants, infrared absorbing and blocking agents, and the like.

Optionally, an infrared attenuating agent such as carbon black, graphite, and titanium dioxide may be incorporated into the foam to reduce thermal conductivity. Suitable carbon blacks include thermal black and furnace black. The agent may be incorporated by dry-blending with polymer resin prior to melting and mixing or may be pre-compounded with the polymer resin to form a concentrate which subsequently can be let down or diluted with additional polymer resin during melting and mixing to achieve the desired concentration of agent. Concentration of the infrared attenuating agent preferably ranges from about 1 to about 10 phr and more preferably from about 2 to about 7 phr. As used herein, "phr" means parts per hundred parts by weight of alkenyl aromatic polymer material.

The present foams are useful in a variety of insulating applications such as in buildings, roofing, and vacuum insulation panels.

EXAMPLES

Examples 1 and 2 and Control Foam 1

Open cell, extruded alkenyl aromatic polymer foams according to the present invention were made employing an ethylene/vinyl acetate copolymer (EVA). A control foam
5 was made with substantially the same foam forming formulation except without the EVA at substantially the same processing conditions except for foaming temperatures. The physical properties of the foams, including open cell content, were determined and compared.

The foams were made on an apparatus comprising an extruder, a mixer, a
10 cooler, and an extrusion die in series. The alkenyl aromatic polymer and the EVA were dry blended and fed to the extruder where they were melted and blended to form a polymer melt. The polymer melt was conveyed to the mixer where a blowing agent was blended therein to form a polymer gel. The gel was conveyed through the die to a region of reduced pressure to form the expanded foam product.

The alkenyl aromatic polymer was a polystyrene of weight average molecular
15 weight of 192,000 according to size exclusion chromatography (SEM). The EVA was ELVAX (trademark of du Pont) 150 having a vinyl acetate monomeric content of approximately 33 percent by weight of the total weight of the copolymer. The polymer feed employed was 97 weight percent polystyrene and 3 weight percent EVA. The control foam
20 was made with 100 percent polystyrene.

The blowing agent mixture was the following: 8.8 parts per hundred parts
polymer (per) HFC-134a, 2.5 phr ethyl chloride, and 1.1 phr carbon dioxide. Additives
employed were the following: 1 phr glycerol monostearate as a cell size enlarger, 0.2 phr
25 tetrasodiumpyrophosphate as an acid scavenger, 0.05 phr barium stearate as an extrusion aid, 0.5 phr linear low density polyethylene as a cell size enlarger, 0.1 phr of a 10 percent concentrate of blue pigment in polystyrene, and 1 phr hexabromocyclododecane as a fire retardant.

The foam of Example 1 with 3 percent by weight of EVA exhibited a 95.2
percent open cell content compared to a 5.0 percent open cell content for the control foam.
30 The foam of Example 2 also with 3 percent by weight of EVA exhibited a 53.4 percent open cell content compared to a 5.0 percent open cell content for the control foam. Due to the presence of the EVA, foaming temperatures could be reduced and cross-sections increased

for both foams of the examples compared to that of the control foam. Results are set forth in Table 1.

TABLE 1

Physical Properties for the Foams of Example 1 and Control Example 1

	Control Foam	Example 1	Example 2
Foaming Temperature (°C)	123	119	113
Density (without skin), pcf (kg/m ³)	2.4(38)	2.45(39.2)	2.84(45.5)
Thickness, inch (centimeters)	0.57(1.4)	0.71(1.8)	0.97(2.5)
Width, inch (centimeters)	7.63(19.4)	9.81(24.9)	8.06(20.5)
Vertical Cell Size (millimeters)	0.07	<0.1	0.07
Open Cell Content (volume percent)	5.9	95.2	54.1

5 Examples 3 and 4 and the Control Foams 3-4

Open cell, extruded alkenyl aromatic polymer foams according to the present invention were made employing an ethylene/vinyl acetate copolymer (EVA). Corresponding control foams were made without the EVA at substantially the same processing conditions and with substantially the same foam-forming formulations as the foams of the invention.

10 The physical properties of the foams, including open cell content, were determined and compared.

The alkenyl aromatic polymer was a polystyrene of weight average molecular weight of 132,000 according to SEM. The EVA was the same as employed in Example 1.

The polymer feed employed varying contents of EVA with the balance being polystyrene.

15 The control foams were made with 100 percent polystyrene. The blowing agent mixture was the following: 2.8 parts per hundred parts polymer (per) HFC-134a, 1.8 phr ethyl chloride, and 2.4 phr carbon dioxide.

Graphite was employed as an infrared blocking agent, and calcium stearate was employed as a nucleating agent in some formulations.

20 The foams were made with the apparatus described in Example 1. After extrusion, the foams were compressed approximately 60 percent and exposed to a vacuum of 0.2 torr R-values for the foams of the examples and the control foams were determined

by calculating the reciprocal of the thermal conductivity as measured in BTU-inch/hour-foot²-F°.

It was found that the relatively small EVA loadings in the foams of the examples resulted in significantly increased open cell content compared to the corresponding control foams at the same or substantially the same foaming temperatures resulting in improved R-values. Results are set forth in Table 2.

TABLE 2

Physical Properties for the Foams of Examples 3-4 and Control Foams 3-4

	Control Foam 3	Control Foam 4	Example 3	Example 4
EVA (phr)	none	none	1.0	0.5
Graphite(phr)	3	2	3	2
Calcium Stearate (phr)	none	0.25	none	0.25
Foaming Temperature (°C)	131	130	130	130
Fresh Density (skived) 2.37 lbs./ft ³ (kg/m ³)	(37.9)	2.36 (37.8)	2.32 (37.1)	2.28 (36.5)
Open Cell Content (percent)	76	88	97	97
Density After Compression lbs./ft ³ (kg/m ³)	5.93 (94.9)	5.90 (94.4)	5.48 (87.7)	5.97 (95.5)
Percent Compression	60	60	60	61
R-value per inch at 0.2 torr	18	30.4	34.5	36.7

A method of enhancing open cell formation in making extruded alkenyl aromatic polymer foams of about 30 percent or more open cell content, heating an alkenyl aromatic polymer material comprising greater than 50 weight percent of alkenyl aromatic monomeric units to form a polymer melt, optionally incorporating a nucleating agent into the polymer melt, incorporating a blowing agent into the polymer melt to form a foamable gel, the foamable gel being cooled to a desirable foaming temperature, the foamable gel being extruded through a die into a region of reduced pressure to form the foam, wherein the improvement comprises incorporating into the polymer melt at from about 0.1 to about 7 percent based upon the weight of the alkenyl aromatic polymer material an ethylene copolymer having a Vicat softening point of about 85°C or less, the ethylene copolymer

having an ethylene monomeric content of about 50 percent to about 97 percent based upon the total weight of the ethylene copolymer.

1. A method of enhancing open cell formation in making extruded alkenyl aromatic foams of about 30 percent or more open cell content, heating an alkenyl aromatic polymer material comprising greater than 50 weight percent of alkenyl aromatic monomeric units to form a polymer melt, optionally incorporating a nucleating agent into the polymer melt, incorporating a blowing agent into the polymer melt to form a foamable gel, the formable gel being cooled to a desirable foaming temperature, the formable gel being extruded through a die into a region of reduced pressure to form the foam, wherein the improvement comprises incorporating into the polymer melt at from about 0.01 to about 7 percent based upon the weight of the alkenyl aromatic polymer material an ethylene copolymer having an Vicat softening point of about 85°C or less, the ethylene copolymer having an ethylene monomeric content of about 50 percent to about 97 percent based upon the total weight of the ethylene copolymer.

2. The method of Claim 1, wherein the ethylene copolymer comprises an ethylene/vinyl acetate copolymer.

3. The method of Claim 1, wherein the ethylene copolymer comprises an ethylene/acrylic acid copolymer.

4. The method of Claim 1, wherein the ethylene copolymer comprises an ionomer.

5. The method of Claim 1, wherein the ethylene copolymer is an ethylene copolymer made with constrained geometry or metallocene catalyst technology.

6. The method of claim 1, wherein the ethylene polymer comprises and ethylene/methacrylic acid copolymer.

7. The method of claim 1, wherein the ethylene copolymer comprises an ethylene/methylacrylate copolymer.

8. The method of claim 1, wherein the ethylene polymer comprises an ethylene/ethyl-acrylate copolymer.

9. The method of Claim 1, wherein the foam has an open cell content of about 50 percent or more.

10. The method of Claim 1, wherein the foam has an open cell content of about 90 percent or more.

11. The method of Claim 1, wherein the foam has an open cell content of about 95 percent or more.

12. The method of Claim 1, wherein the ethylene copolymer is incorporated at from about 0.2 to about 5 percent based upon the weight of the alkenyl aromatic polymer material.

13. The method of Claim 1, wherein the ethylene copolymer is incorporated at from about 0.3 to about 3 percent based upon the weight of the alkenyl aromatic polymer material.

14. The method of Claim 1, wherein the ethylene copolymer has a Vicat softening point of about 70°C or less.

15. The method of Claim 1, wherein a nucleating agent is incorporated at from about 0.01 to about 5 parts by weight per hundred parts alkenyl aromatic polymer, the blowing agent being selected from the group consisting of 1,1-difluoroethane (HFC-152a), 1,1,1-trifluoroethane (HFC-143a), 1,1,1,2-tetrafluoroethane (HFC-134a), chlorodifluoromethane (HCFC-22), carbon dioxide (CO₂), and difluoromethane (HFC-32) and comprising 50 mole percent or more of the total number of moles of blowing agent, the blowing agent being incorporated at from 0.06 to about 0.17 gram-moles per kilogram of polymer.

16. The method of Claim 1, wherein the amount of blowing agent incorporated is from about 0.2 to about 5.0 gram-moles per kilogram of alkenyl aromatic polymer, the foaming temperature being at from about 3°C to about 15°C higher than the highest foaming temperature for a corresponding closed-cell foam of substantially equivalent density and cell size made with a substantially equivalent composition in a substantially equivalent process, the foaming temperature being at from about 113°C to about 145°C.

17. An extruded, open cell alkenyl aromatic polymer foam, the foam comprising: an alkenyl aromatic polymer material comprising greater than 50 percent by weight of alkenyl aromatic monomeric units, the foam having a density of about 16 to about 250 kg/m³, the foam having an average cell size of about 1.2 millimeters or less, the foam having an open cell content of about 30 percent or more, the foam having about 0.1 to about 7 percent of an ethylene copolymer based upon the weight of the alkenyl aromatic polymer material, the ethylene copolymer having a softening point of about 85°C or less, the ethylene copolymer having an ethylene monomeric content of about 50 percent to about 97 percent based upon the total weight of the ethylene copolymer.

INTERNATIONAL SEARCH REPORT

International Application No PCT/US 98/12999		
A. CLASSIFICATION OF SUBJECT MATTER IPC 6 C08J9/00 C08J9/12 C08J9/14 //C08L25/06		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) IPC 6 C08J		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the International search (name of data base and, where practical, search terms used)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P, X	WO 97 22656 A (GRACE W R & CO) 26 June 1997 see claims ---	1-17
A	US 4 452 751 A (MCCULLOUGH THOMAS W ET AL) 5 June 1984 see claims ---	1-17
A	DATABASE WPI Section Ch, Week 8626 Derwent Publications Ltd., London, GB; Class A13, AN 86-167210 XP002079902 & JP 61 101538 A (SEKISUI PLASTICS CO LTD) , 20 May 1986 see abstract --- <div style="text-align: center;">-/--</div>	1-17
<div style="display: flex; justify-content: space-between;"> <input checked="" type="checkbox"/> Further documents are listed in the continuation of box C. <input checked="" type="checkbox"/> Patent family members are listed in annex. </div>		
* Special categories of cited documents :		
<div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> </div> <div style="width: 45%;"> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"3" document member of the same patent family</p> </div> </div>		
Date of the actual completion of the international search	Date of mailing of the international search report	
7 October 1998	16/10/1998	
Name and mailing address of the ISA	Authorized officer	
European Patent Office, P.O. 5616 Patentlaan, 2 NL - 2260 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Oudot, R	

INTERNATIONAL SEARCH REPORT

International Application No
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p> DATABASE WPI Section Ch, Week 8332 Derwent Publications Ltd., London, GB; Class A13, AN 83-732202 XP002079903 & JP 58 111834 A (NIPPON STYRENE PAPER KK) , 4 July 1983 see abstract ----- </p>	1-17

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